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PATENT

Attorney's. Docket No. 99-960

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NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of:

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For: POWER CONTROL FOR ACTIVE LINK QUALITY PROTECTION IN CDMA NETWORKS

Certification Under 37 CFR 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date 8/22/00 in an envelope as "Express Mail Post Office to Addressee" mailing label EK673491908US addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

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Enclosed are:

[5] pages of specification
[5] pages of claims
[1] page of abstract
[1] sheet of formal drawings.
[2] pages of declaration and power of attorney.
[ ] pages of assignment and assignment recordation form
[ ] pages of information disclosure statement
[ ] pages of form 1449
[ ] references
[1] return postcard

CLAIMS AS FILED

	NUMBER FILED	NUMBER EXTRA	RATE	BASIC FEE $690.00
TOTAL CLAIMS	16 - 20	0 x	$18.00	0.00
INDEPENDENT CLAIMS	10 - 3	7 x	$78.00	546.00
MULTIPLE DEPENDENT CLAIMS(S)		0 x	$260.00	0.00
		TOTAL FILING FEE		$1236.00

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POWER CONTROL FOR ACTIVE LINK QUALITY PROTECTION IN CDMA NETWORKS

FIELD OF THE INVENTION

The present application claims priority based on the provisional application Serial No. 60/169,849, filed on December 9, 1999, the entire contents of which are incorporated by reference. The present invention relates to protecting a Code Division Multiple Access (CDMA) data network from excessive interference in order to maintain the quality of service of the data network. A power control approach is disclosed to scale the power of all active links to achieve link protection and improved tolerance to interference.

BACKGROUND OF THE INVENTION

Broadband CDMA systems, in the near future, will provide a wide range of multi-media services including voice, data, and video. With multi-media traffic, users present the network with a range of bandwidth and quality of services (QoS) requirements.

The performance of a CDMA system is interference limited. Interference can cause disruption in the service of dedicated bandwidth or circuit data users who have been admitted into the system and guaranteed frame error rate and throughput targets. In order to provide the quality of service ("QoS") guaranteed to data users, the interference in the system must be tightly controlled. Multi-access interference can be regulated by controlling the transmit powers of the users. Power control techniques that are designed only to combat fading, suffer the problem that an active new user can cause the signal to noise ratios of operational users to drop below their required threshold. Therefore, power control techniques must be designed to adjust the power when new users are admitted to the system, to maintain their guaranteed quality of service and for active link quality protection.

A detailed mathematical analysis of the affect of transmit power on the interference margin in a communications channel and how the link protection algorithm of the present invention was derived is presented in the following references, which are hereby incorporated by reference in their entirety:

1. D.V. Ayyagari and A. Ephremides in Power Control for Link Quality Protection in Cellular DS-CDMA Networks with Integrated (Packet and Circuit) Services. MOBICON 99 (Conference) September 15, 1999.

2. D.V. Ayyagari, Capacity and Admission Control in Multi-Media DS-CDMA Wireless Networks. Ph.D. Dissertation, University of Maryland, College Park, 1998.

SUMMARY OF THE INVENTION

In Code Division Multiple Access (CDMA) systems the capacity is a function of the total interference on the system, which in turn depends on the received powers of all the users sharing the same frequency spectrum. A dynamic power control algorithm is used to control the received signal strength at the base station of a CDMA network. The transmit power levels of users are controlled by up/down commands issued on a forward link from the base station.

The base station dynamically computes the maximum received signal strength available from each user including the effect produced by path gain over the signal path to the base station. The base station then computes the minimum power required from each user that will meet the QoS and frame error rate requirements of each user. The maximum to minimum power ratio is determined for each user and the power ratio closest to unity, the weakest link, is determined. The weakest link power ratio is then used to scale upwardly the minimum power level of each user to provide the optimal operating power that will meet each user's "Quality of Service" (QoS) and frame error rate requirements with the lowest addition of interference to the network.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the steps in the algorithm of the present invention.

DETAILED DESCRIPTION

For simplicity, the present invention will be described as used with a cellular communication system having mobile user in communications with a cell base station. The inventive system is implemented at the base station but it is applicable to both the forward and reverse links. Forward = base to mobile, while reverse = mobile to base.

The link protection process begins at 5 of Figure 1, where each user of the network is currently operating at individual power levels sufficient to meet its signal to noise ratio and quality of service requirements. The transmit power levels of the users are controlled by the base station via up/down commands issued on the forward link. At this step, the mobile units are operating at a power greater than the minimum required for their signal to noise ratios but less than or equal to their peak transmit power capability which is fixed by battery power. The weakest link needs a minimum transmittal power almost equal to the maximum transmittal power.

The base station at step 7 dynamically calculates the path gain for each of the mobile units. This can be done by the base station issuing a command to the mobile unit to transmit at a known power level and then measuring the received power. Received power = T_x x path gain.

At step 9, the base station computes the maximum received power possible from each mobile unit. At connection or communication set-up, the mobile unit identifies the type of mobile unit being used. The peak transmit power capability of each class of mobile unit is known to the base station. From the path gain measurements, the base station computes the maximum received power possible from each mobile user. The maximum received power equals peak transmit power times path gain.

At the next step 11, the base station computes the minimum received signal power it needs to receive in order to maintain the quality of service and frame error rate requirements. The limitations of the base station are known so the minimum received signal must be strong enough to overcome these limitations to meet the user's service requirements. The minimum received power can be computed using the same equation used to solve for maximum received power but substituting minimum received power, which is known, and solving for minimum

transmit power. Like the maximum power, it can also be determined by sending command signals from the base station ordering the mobile unit to reduce power until the signal to noise ratio is reached where the mobile unit is just meeting its quality requirements. Testing in this manner, however, adds unnecessary noise to the data link.

A power ratio is then determined at 13 by dividing the maximum received power of each mobile unit by the minimum received power each mobile unit needs to meet its signal to noise ratio and quality requirements. The lowest power ratio determined for all of the mobile units, the power ratio of the weakest link, is selected for use as the scaling factor. The weakest link needs a minimum transmittal power almost equal to the maximum transmittal power.

The lowest power ratio or scaling factor is used at 15 to raise the minimum transmit power of all of the active mobile units. The base station raises the powers of all active mobile units by the up/down commands on the forward link by the scaling factor.

If the network is not heavily loaded, it is possible to raise the operating power of the active users on the network. Therefore, it is necessary to determine an alternate scaling which does not raise the user powers beyond what is necessary. Let $\hat{B}$ be the required interference margin. Then the scaling factor a that would provide the interference margin $\hat{B}$ can be determined as follows:

$$\hat{B} = \frac{\hat{a}s_i^{\min}}{T_i} - \sum_{j \neq i} \hat{a}s_j^{\min} - \eta$$

$$\hat{a} = \frac{\hat{B} + \eta}{\frac{s_i^{\min}}{T_i} - \sum_{j \neq i} s_j^{\min}}$$

where i is the index of the code that has lowest minimum power $s_i^{\min}$. This results in the lowest power vector, which maintains link quality and provides the desired interference margin $\hat{B}$.

In accordance with the Telecommunications Industry Association's interim standard IS-95 the power control algorithm can issue update instructions at the rate of 800 updates/second to each active mobile user. Operating at approximately 850 MHz the path gain for a mobile unit

can change in a matter of inches. Interfering structures and foliage have a significant affect on the path gain.

Knowing the path gain as determined by the base station, it issues a command for each active mobile unit to transmit at a known power. (The base station, upon initial contact with the mobile user, ascertains the type of equipment the mobile unit is using. The base station has stored in memory the characteristics of the mobile unit and what its power capability is for the unit.) The Base station then measures the power received. Knowing the path gain and the received power, base station determines the maximum received power possible at the base station for each user's mobile unit.

The link protection system will preferably be used continuously while the network is in operation to dynamically determine the operating power of the active mobile users since the power ratio or scaling factor and the path gain varies continuously as a user moves relative to the base station. The system is proven to yield significant improvements in capacity while maintaining the quality of service guarantees made by the network to high capacity users currently active on the system.

While the invention has been disclosed in connection with the preferred embodiments shown and described in detail, various modifications and improvements thereon will become readily apparent to those skilled in the art. Accordingly, the spirit and scope of the present invention is to be limited only by the following claims.

CLAIMS

What is claimed is:

1. A method for controlling the level of interference on a CDMA network having mobile units in contact with a base station comprising the following steps:

determining the received power of a first signal from each mobile unit;

determining the received power of a second signal from each mobile unit;

determining the power ratio of said first signal relative to said second signal;

selecting the lowest power ratio from all of the power ratios determined; and

using said lowest power ratio to scale upwardly the transmit power used to produce said second signal to establish a new transmit power for each mobile unit on the CDMA network.

2. A method for controlling the interference on a CDMA network as set forth in claim 1, wherein each second received signal is lower in power than said first received signal.

3. A method for controlling the interference on a CDMA network as set forth in claim 1, wherein said second received signal is the minimum received signal each unit can use which still meets the signal to noise ratio requirement.

4. A system for controlling the level of interference on a CDMA network having mobile units in contact with a base station comprising:

means for causing said mobile units to send a first signal to said base station;

means for determining the path gain of said first signal;

means for delivering the received signal strength of a second signal using the path gain of said first signal;

means for determining the received signal strength of a third signal, lower in power than said second signal, using the path gain of said first signal;

means for using the received signal strength of said first and second signals at said base station for determining a power ratio for each mobile unit;

means for selecting the lowest power ratio; and

means for using said lowest power ratio for scaling upwardly the transmit power each mobile unit used for said second signal to set a new transmit power level for each mobile unit on said CDMA network.

5. A method for controlling the level of interference on a CDMA network as set forth in claim 4, wherein said second signal is lower in power than said first signal.

6. A system for protecting a wireless digital communications network from interference from the use of excessive power by mobile users in active communication with a base station comprising;

means for determining the maximum received power capability of each mobile user at said base station;

means for determining the minimum received power, which is capable of meeting the communications quality requirements of each user with said base station;

means for determining the ratio of maximum received power to minimum received power of each user;

means for determining the lowest user power ratio; and

means for using said lowest user power ratio to scale upwardly the minimum power of each user which scaled power is set as the user operating power by said base station.

7. A system for controlling interference in a CDMA wireless communications network having mobile users in contact with a base station comprising;

means for determining the maximum received power of each active user at said base station;

means for determining the minimum received power each user can use while maintaining an acceptable communications link between said user and said base station;

means for determining the ratio of maximum received power to minimum received power of each of said users and for determining the lowest power ratio used; and

means for using said lowest power ratio to scale upwardly the transmit power of each user that was used to produce the minimum received power at said base station to arrive at a new transmit power for each active user to use in communication with said base station.

8. A CDMA cellular communications network wherein an active mobile user in contact with the base station is operating at a power level determined by multiplying the minimum power that said user can use for quality communication with said base station by a scaling factor determined by the lowest ratio of maximum received power to the minimum received power of all of the users at the base station.

9. A method for reducing the level of interference of a CDMA cellular communications network comprising;

determining the maximum received power of each user of the network at a base station;

determining the minimum received power of each user, which is capable of maintaining quality communication with said base station;

calculating a power ratio for each user by dividing a users maximum received power by the user's minimum received power;

selecting the lowest power ratio to use as a scaling factor; and

multiplying the power level used by each user in determining the minimum received power by said scaling factor to arrive at a new power level for use in communication with said base station.

10. A method for maintaining the communication quality of a wireless digital data network comprising:

determining the maximum receive power from each active network user;

determining the minimum received power which an active network user can use while maintaining quality communication within the frame error rate;

determining the maximum received power to minimum received power ratio of each network user;

scaling upwardly the transmitting power of each user by multiplying the transmit power which produced the minimum received power by the lowest power ratio to produce a new operating power for all users not already operating at the new power level.

11. A method for maintaining the communication quality of a wireless digital data network as set forth in claim 10, wherein the transmitting power of each network user is

controlled at a level determined by a ratio of maximum to minimum received power of the weakest network user.

12. A wireless digital communications network wherein the operating power of each user is scaled upwardly by the lowest maximum to minimum received power ratio determined for all of the active network users.

13. A wireless digital communications network as set forth in claim 12, wherein the operating power of each network user is determined by multiplying the power used to produce the minimum received power by the maximum to minimum received power ratio of the weakest user.

14. A method for providing active link quality protection while improving capacity in wireless communication systems, comprising the steps of:

for a plurality of active users, recognizing error rate requirement and minimum and maximum transmit power capabilities for each active user;

assigning a first power level to each active user;

assigning a minimum transmit power so each active user's desired error rate is satisfied;

determining the maximum received power possible from any active user;

determining the smallest ratio of peak received power to minimum received power of each active user;

scaling the transmit powers of all active users that was used to produce the minimum received signal by the smallest ratio determined above.

15. A method for adjusting power of new and active users and providing active link quality protection and improving capacity in wireless communication systems, through the steps of:

assigning feasible power levels to active users having minimum and maximum transmit power capabilities;

determining the minimum transmit power required by the active users so each user's desired error rate is satisfied;

determining the maximum received power possible from any active user based on device peak transmit power capability and propagation characteristics;

determining the weakest link; that is, the user with smallest ratio of peak received power to minimum received power;

scaling the powers of all active users by the ratio determined above if maximum capacity is desired; and

scaling the powers of all active links by a factor less than the optimal as determined by the number of new users to be activated and the resulting new interference that must be tolerated.

16. A method for adjusting power of new and active users and providing active line quality protection and improving capacity in wireless communication systems as set forth in claim 15, wherein for less than optimal conditions, the scaling factor $\hat{a}$ is used where:

$$\hat{a} = \frac{\hat{\mathrm{B}} + \eta}{\frac{s_i^{\min}}{\mathrm{T}_i} - \sum_{J \neq i} s_J^{\min}}$$

POWER CONTROL FOR ACTIVE LINK QUALITY PROTECTION IN CDMA NETWORKS

ABSTRACT OF THE DISCLOSURE

The present invention relates to a system and method for dynamically limiting the power of all users of a CDMA digital data link to maximize throughput and reduce interference among users of the link. In the operation of the data link, the maximum power available from each user of the link is determined along with the minimum power needed from each user to meet its link service requirement, that is, quality of service and frame error rate requirements. The maximum to minimum power ratio is derived for each user and the lowest power ratio, that is, the power ratio closest to unity is selected and used to scale upward the minimum power levels of all users of the data link. The resulting power level establishes the interference margin or slack available for all users of the data link and the interference slack available for new users to be admitted to the data link.

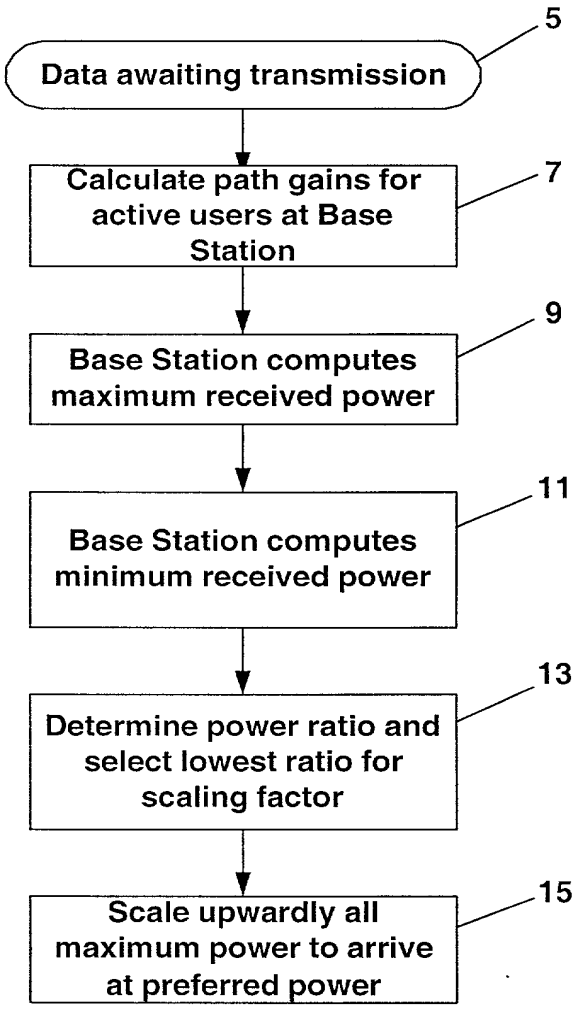
Data awaiting transmission
5
Calculate path gains for active users at Base Station
7
Base Station computes maximum received power
9
Base Station computes minimum received power
11
Determine power ratio and select lowest ratio for scaling factor
13
Scale upwardly all maximum power to arrive at preferred power
15

Fig. 1

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DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

Attorney Docket No. **99-960**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

POWER CONTROL FOR ACTIVE LINK QUALITY PROTECTION IN CDMA NETWORKS

the specification of which (check one) [x] is attached hereto. [ ] was filed on as Appln. Serial No. and was amended on (if applicable). I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed
(Number)	(Country)	(Day/Month/Year filed)	[_] Yes [_] No

I hereby claim the benefit under Title 35, United States Code, 119(e) of any United States provisional applications(s) listed below.

60/169,849	12/9/99
(Application Number)	(Filing Date)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date for this application:

(Appln. Serial No.)	(Filing Date)	(Status--patented, pending, abandoned)

Attorney Docket No. **99-960**

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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